# The effects of artificial water holes on the distribution of elephants and other mammalian herbivores in Savuti, Northern Botswana

**Evert Avril Kasiringua**

Høgskolen i Hedmark

Master Thesis at Faculty of Forestry and Wildlife Management

HEDMARK UNIVERSITY COLLEGE

2010

# Table of content

## Abstract

It has been argued that the wide-scale provision of artificial surface water in semi-arid savannas may result in homogenisation of foraging habitats, compromising biodiversity and ecosystem resilience. This study looks at the distribution of mammals around two waterholes namely Rhino vley and Marabou vley in Northern Botswana Savuti, Chobe National Park. This is explored by examining consistencies within and differences between distribution patterns of herbivore feeding groups on the different soil types and distances from the waterholes. In this study I used tracks and dung counts plus visual observations to look at the distribution of species around the two artificial water wholes using ordinations to show the distribution patterns. Multivariate analysis and Canonical analysis was used to to treat the data. The results in this paper (from the ordinations) show that animals densities decreased with increasing distance from the water holes and that body size plays a major role in the distribution of species around artificial water holes as obseved in other studies. A similiar study should be done in the dry season in Savuti to have more precision on the assemblages of different species around the artificial waterholes, in order for management implications to be taken in consideration if need be.

# Acknowledgement

It is impossible to write an article of this nature without the assistance of many people. The list of acknowledgement is long, from Norway in northern Europe to Namibia and Botswana in southern African. I thank the Hedmark University College for giving me an opportunity to broaden my knowledge in wildlife management. The staff at Evenstad College especially, Harry Andreassen and Barbara Zimmermann for their assistance from day one. I would also like to thanks Torstein Storaas, Kjell Langdal, Ostein Vaagen, Mona Sagen, and the best librarian Kari Seeberg for never turning their backs on me during my four years with them at Evenstad.

Many thanks go to the Botswana Department of Wildlife and National Parks (DWNP) in Savuti for their support and engagement during the three months of fieldwork, especially Phake for his timeless contribution both on a personal and professional level. Special thanks also go to the supervisor at DWNP for always having something productive to say and Ralph for his field assistance and protection in the field. Much appreciation goes to Cecilia Aldemo and Martin Skram Vatne for their contributions to this thesis, especially for being a big part of my Botswana family. My heartfelt appreciation also goes to my supervisor Professor Christina Skarpe for the support during the data analysis and write-up, since without her detailed and high quality information this thesis would not have been written. Great gratitude goes to the Integrated Community-based Ecosystem Management project (ICEMA) for granting me a study leave to be able to complete my thesis when I actually didn't deserve it, especially to Jo Tagg the project co-coordinator for being so understanding. I would also like to acknowledge two very special people that I met in my time in Norway, Per Moels and his Wife Kathy Moels. I would like to thank you both for all your love and for never giving me a reason to get home sick but most of all for accepting me into your family and for treating me like I belong.

This thesis is dedicated to my daughter Avril Ngariande Kasiringua and my late grand mother Mrs. Ngariande Kasiringua. I know that I wouldn't have reached this level of education if it weren't for your love and motivation even when times were hard. You will always be in my heart and thoughts, love you endlessly.

# 1. Introduction

The composition of large herbivore communities varies considerably across southern Africa (du Toit 1995). Coe et al. (1975) suggested that variation in climate, mainly in precipitation, affect the production of plant material and indirectly the carrying capacity of the ecosystem in which these animals occur. Putman, (1996) suggests that as long as the overlap in potential resource use is incomplete, species do coexist even if there are overlaps in their fundamental niches (Makhabu, 2005). Individual species can occupy different and non overlapping post-interactive niche in the presence of the other potentially competing species (Putman, 1996). According to Cromsigt et al. (2009), for the savannah ungulates, body mass is said to drive habitat selection and allow species coexistence, where large species use a larger proportion of the landscape than smaller species, because of a wider food quality tolerance which allows them to use a higher diversity of habitat types. Hence, large bodied browsers are more evenly distributed over the landscape than small ones, in other words smaller bodied species such as impala’s have a variety of range sizes whereas large bodied species like eland (*Tragelaphus oryx*) and elephants (*Loxodonta africana),* have only large ranges. This would also suggest that high habitat heterogeneity would facilitate diverse assemblages of different sized ungulates (Aava, 2001). Cromsigt et al. (2009), continues by suggesting that digestive physiology further transform the relationship between ruminants and non ruminants because of the wider diet tolerance that non ruminants have.

Furthermore, the relationship between rainfall and soil nutrients may also have a role in the distribution of the animals, since rainfall promotes large plant biomass production and soil nutrients promotes high concentration of nutrients in the plant tissues (Olff et al. 2002). In support of the above Coe et al. (1975), Watson, (1972) Leuthold, (1973) and Sinclair, (1974) have noted a relationship between annual rainfall and the large African herbivore biomass. Phillipson, (1975) indicated that elephant populations in the Tsavo National Park may have infect been governed by temporal and spatial variations in primary production. If this is true than one can assume that the highest herbivore diversity should occur in locations with high nutrient content and intermediate moisture (Olff et al. 2002).

Spatial and temporal variation in water availability may also be linked to the distribution of different species, (Epaphras et al 2007). Western, (1975) suggested that wild animals drink more regularly during the dry season in order to meet their body requirements of water, he then went on to suggest that their daily and seasonal migrations are to a degree determined by spatial and temporal surface water distribution (see Epaphras et al 2007). Water necessities are said to generally scale with body size (du Toit 2002, Brown 2006), however some species are more or less independent of surface water e.g. the springbok (*Antidorcas marsupialis)* and klipspringer (*Oreotragus oreotragus*) but are likely to drink when water is available. Browsers or mixed feeders e.g. Lichtensteins hartebeest (*Alcelaphus lichtensteinii)* and gemsbok (*Oryx gazella)* are also more likely to be water independent (du Toit, 2002), obtaining the bulk of their water from forage especially in the wet seasons. Species adapted to arid environments often have physiological adaptations to reduce sweating, store water, recycle water more efficiently, or reduce water losses in faeces and urine (Coughenour, 2008), like the gemsbok. Smit et al. (2007) suggested that most grazer species are associated with water points, e.g. zebra, whereas browsers and mixed feeders are indifferent to water points e.g. elephants and eland. Thus, differences in water requirements as mentioned above may cause animals of different species to distribute differently around the water points. Mobility is another factor that can influence the distributions of species around water points, some species like elephant, elands, and roan antelope (*Hippotragus equinus*) walk long distances from the water points to feed whereas smaller species like the impala (*Aepyceros melampus*) preferably feed closer to the water points. This means that the source of water becomes the focus of grazing activity, which results in a zone of attenuated impact (a piosphere) around each water point (Lange, 1969).

Piospheres are said to be the product of the impact of a disturbance (e.g., wildlife grazing/browsing) at patches such as water points, and mineral licks, (Forman and Godron, 1981). The disturbance's impact is highest at the core of a resource area and attenuates radially with increased distance from the patch centre (Andrew, 1988). ‘’Lange (1969), researching the effects of sheep grazing at water points, coined the term piosphere, where "pios" is the Greek word for drink and "sphere" is representative of the weakening impact of the disturbance equally isolated from the resource patch centre’’, (Andrew, 1988).

As a result, the areas closest to the water are normally heavily grazed /browsed and may particularly in the dry season be more or less devoid of food, forcing animals to feed away from the water to search for forage. The ecological effects of piosphere have been debated, especially for areas where artificial water holes are newly introduced. In general, intense use by wildlife of these areas often has strong effects on vegetation in the surroundings, e.g. by killing trees (particularly in areas with elephants) and reducing woody species regeneration (Moe et al. 2008). Elephants can play an important role in the dynamics of the structure and composition of African savannas, as shown by Baxter and Getz (2005) and Dublin et al. (1990). Many sorts of elephant impact on vegetation structure have been shown but the most obvious would be the knocking down and uprooting of trees and bushes leading to a reduction in the area of woodland (Mosugelo *et al.* 2002). According to Valeix et al. (2007), elephants are animals that can indirectly affect the availability of resources (food and shelter) for other species by changing the structure of the woody vegetation. In a larger perspective the addition of artificial water holes eventually changes the heterogeneity of the environment (food resources, competition) for herbivores, with some effects on animal community composition and species diversity (Knight 1995, Owen-Smith 1996).  Thus, the structure and function of the African savanna ecosystems are strongly influenced by the ungulate communities, e.g. composition of body size classes and feeding guilds as suggested by du Toit & Cumming (1999).

Artificial provision of water for wildlife in game areas, usually from drilled bore holes is increasingly common in southern Africa. In fragmented game areas without natural or permanent water it is a necessity, whereas in many other areas it is used to attract animals for game viewing or hunting or to reduce dry season mortality. The idea of placing artificial waterholes in the Botswana national parks (e.g. Chobe) was implemented by the Department of Wildlife and National Parks and other NGO's in the early 1990's. This was done to reduce the concentration of Game at the permanent water bodies, especially of the big game, elephants in particular, which were documented to have caused a lot of habitat destruction or modification around the water bodies (Mordi, et al. 1989). Kalwij et al. (2009) mentioned that an effective means to manipulate the spatiotemporal distribution of water-dependent species is through the provision of artificial water points (Chamialle-Jammes et al. 2007).

The aim of the present project is to increase the understanding of the effects of artificial water holes in small to intermediate temporal and spatial scale, using two water holes in Savuti, Chobe National Park, Botswana as an example.

## 1.1 Main Objectives:

To asses the distribution of large mammals of different functional types in relation to artificial water holes.

1.1.1 Specifically I want to:

- Determine whether general animal densities decrease with increasing distance from the water.
- Determine whether small bodied water depending species are mostly confined to the immediate vicinity of the water.
- Asses whether the larger bodied animals, particular hind gut fermenting animals like elephants respond least to the distance.
- Determine whether small bodied species such as impala prefer to forage on nutrient rich trees on alluvial/sodic soils, whereas larger species, particularly elephants also browse on nutrient poor and/ or defended species on nutrient poor soils far away from the water.

# 2. Methods and Materials

## 2.1 Study site

Savuti is situated in the Chobe National Park in Northern Botswana and covers an area of about 5,000 square km. The climate is semi-arid and with an annual precipitation between 400mm in the southern part and 650mm in the north eastern parts of the park (Ben-Shahar, 1995). Savuti has mean maximum and minimum temperatures of 35°C and 18°C, with October said to be the hottest and driest month and July being the coldest, (Power & Compion, 2009). The rain normally falls mainly during summer, October to April and the dry season (winter) occurs from May to September. The central parts of Savuti consist of mostly plain grass lands surrounded by woodlands. These grass plains are surrounded by savanna woodlands, shrub savanna and mopane veld, (Stokke et al, 2000). Some of the wooded islands in the grass plains consist of nutrient deficient Kalahari sands. Soil types are in general neutral or slight acid, nutrient poor and with low water holding capacities, poorly structured soils (Ben-Shahar, 2002). Savuti is well known for its channel with a highly variable water flow, which drains into the Mababe depression after its passage across the Savuti marsh. The water unfortunately stopped flowing in 1982, (Walker, 1991) and artificial water has been provided since 1995 at three water holes (Barnes, 1999).

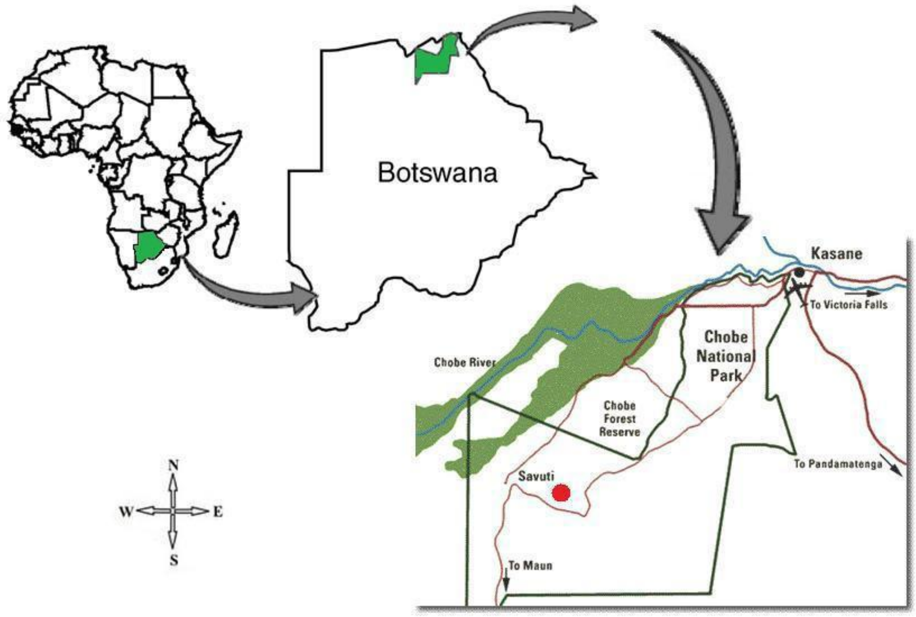


**Figure 1**. Location of study area, Chobe National Park, Savuti. The top left Map was taken from (Kalwij *et al.* 2009) and the lower right map from dktours website.

## 2.2 Data Collection

The data were collected from January to April 2009 during the rainy season. Data were collected at two separate artificial waterholes in Savuti, namely Rhino vley and Marabou vley. There were two transect lines heading west and east at both waterholes, which were 5.5 km in length. Plots of 50m × 50m were placed at 200, 400, 600, 800, 1000, 2000, 4000, 5500, from each waterhole, on each 5.5 km transect line. These plots were found by calculating the GPS coordinates for the exact distance from the waterhole in straight western and eastern direction from GPS point taken at the water holes. The calculated GPS coordinates were regarded as representation of the southwest corners of the plots. Hereafter plots are referred with the initial letter of the water hole (M= Marabou vley; R= Rhino vley) transect as E = east; W = west direction) and distance, (e.g. 200m, 400m), e.g., MW400. Each 50m × 50m plot had 16 sampling transects lines each 50m long, 8 within the plots and another 8 outside the plots, (figure 2). Faeces and footprints (tracks) were counted and identified to species, to define the use of an area by the different species. Figure 2, shows how the sampling transects where laid out at each 50m x 50m plot. All 16 sampling transect lines where 50m in length in all directions and each one was measure thoroughly with a measuring tape. Tracks of all species that crossed any of the 16 sampling transects were counted and identified to species and all faeces that were observed in the plots between the inner transects that acted as sub plots to facilitate counting where counted and identified to species.

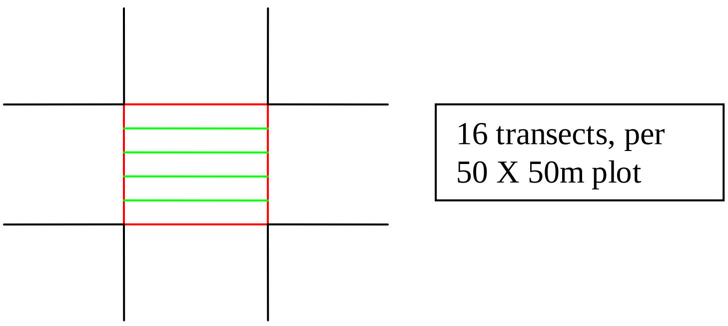


**Figure 2**, shows the 16 transects per 50 X 50m plot. Each 50 X 50m plot (red boarders) had four transects inside (shown in green) and 8 outside the plot (shown in black) all 50m in length.

### 2.2.1 Track counts

I counted and identified tracks at all 32 plots. I walked each transect line and counted and identified all tracks of animals that had crossed each transect line, which was then recorded. This was based mostly on my own experiences of animal tracking as a boy scout, which was aided by two species tracks identification books by (Walker, 1996) and (Cillie, 2007) with all the track and pellet measurements. A ruler was used to measure the tracks and compare them to the measurements given in the two books and by Phake (game scout).

### 2.2.2 Faeces counts

All faeces were counted in the plot, using the space between the inner transect as sup plots to facilitate counting. This was done at all 32 plots where, faeces heaps of 30 pellets or more for the small herbivores were considered as one pellet group and 50 and more pellets for the large herbivores were considered and identified to species. This was done with the guidance of a game scout (Phake) from the DWNP, some dung identification books (Cillie, 2007) and by using my own experience.

### 2.2.3 Observations of animals per plot

Animals observed were identified, counted and recorded 3 times at each plot, at arrival, half way before completing the tracks and faeces counts and lastly after completing each plot. This was done and recorded at all 32 plots.

### 2.2.4 Dominating Soil types

Dominating soil types where recorded at all 32 plots. This was done according to soil texture and colour, we expected small bodied animals like the impala to be closer to nutrient rich soils like alluvial/sodic soils, whereas larger species, particularly elephants to also browse on nutrient poor soils far away from the water. The abbreviations for the different soil types where as follows, White and intermediate particles = WI, White and fine particles = WF, Grey and intermediate particles= GI and Grey and fine particles = GF. Generally the whitish soils have higher pH levels and higher concentrations of calcium, phosphate and sodium than grey or pink soils, and soils that are fine in texture have higher pH and mineral/nutrient concentration than those that are coarser.

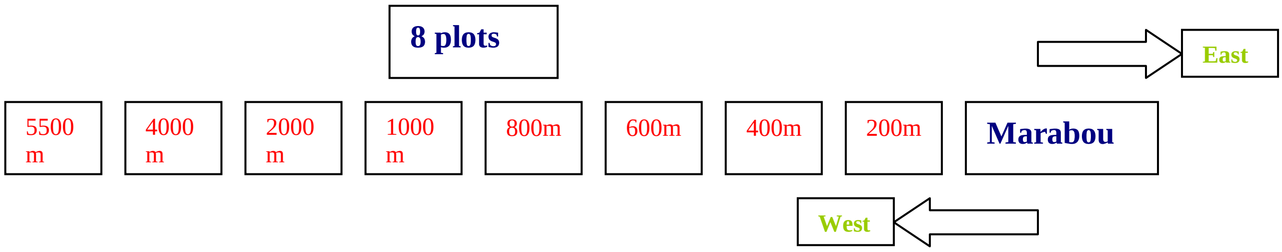


**Figure 3.** Above shows the Marabou water hole and the 8 plots starting from 200m to 5500m west of the water hole. Transects looked the same for both water holes in both directions.

## 3. Data Treatment

Multivariate's statistics handles samples with numerous dependent and independed variables (Gauch, 1982). These samples are common in e.g. ecology, and in biology where the samples may be sampling plots, transects and observational points. Abundance of specie e.g. numbers, density and biomass is often recorded as a response variable providing an estimate of the composition of the assemblages of taxa in the sample. Multivariate's also compares many samples in order to find differences and similarities in species composition and describing communities, whilst relating assemblages or species to environmental variables, e.g., soil types and distances from one point to another (Hair Jr et al. 2009). In multivariate analysis the response variables e.g. specie's number or densities are assumed to respond to environmental gradients by increasing or decreasing in abundance. Multivariate analysis helps us detect patterns in multivariate data in order to reveal structure or test different hypothesis. Classification of species and sample are arranged into groups according to the selected criteria based on similarity/dissimilarity between sample units. The ordinations are axes (extract independent gradients) that explain variables in the response (species data in our case), that often are correlated with gradients in environmental variables (Hair Jr et al. 2009). A statistical program package called CANOCO for Windows 4.5 (Leps and Smilauer, 2003) was used in order to get animals assemblages in ordinations which are considered multivariate methods. CANOCO includes for e.g. the indirect technique of principle components analysis (PCA), (detrended) correspondence analysis and principle coordinates analysis. The program also includes the direct techniques of weighted averaging, canonical correspondence analysis (CCA), canonical variates analysis which is a linear discriminate analysis, (ter Braak, 1988). I tested statistically whether the species were related to the supplied environmental variables by using the Monte Carlo Permutation test (CCA which assumes that species have unimodal distributions along environmental gradients) in CANOCO and included the water holes as co-variables in all ordinations to remove their effects on the distribution pattern of species. A Correspondence Analysis (CA) was used for all ordinations, (track ordination, faeces ordination and observation ordination). A CA, is a non-linear ordination which is not corrected for arch effects. The data was analysed separately and respectively plotted together with environmental variables (distance from waterhole, soil types) in the CA analysis. It was done to interpret and describe how the environment variables affected the species distribution.

**Table 1**, this table illustrates species names (Latin and vernacular names), body mass (Walker, 2007) of animals as considered in this specific paper in groups of three namely, small bodied animals, intermediate bodied and large bodied animals. The table also shows the feeding types and digestives systems of the different species studied in this paper. The acronyms in the figure are: Ruminant = R, Hind-gut fermenter = H, Browsers = B, Grazers = G, and Mixed feeders = B/G.

| | **Latin name** | **Vernacular names** | **Body Mass** | **Digestive system** | **Feeding Type** |
|---|---|---|---|---|---|
| **Small Bodied** | *Aepyceros melampus* | Impala | 47-82 kg ♂<br>32-52 kg ♀ | R | B/G |
| | *Raphicerus campestris* | Steenbok | 9-13 kg ♂<br>11-13 kg ♀ | R | B |
| | *Sylvicapra grimmia* | Grey Duiker | 15-21 kg ♂<br>17-25 kg ♀ | R | B-Mainly |
| | *Phacochoerus africanus* | Warthog | 60-100 kg ♂<br>45-70 kg ♀ | H | B/G |
| **Medium Bodied** | *Damaliscus lunatus* | Tsesebe | 140 kg ♂<br>126 kg ♀ | R | G |
| | *Tragelaphus strepsiceros* | Kudu | 190-270 kg ♂<br>120-210 kg ♀ | R | B |
| | *Connochaetes taurinus* | Wildebeest | 230-270 kg ♂<br>160-200 kg ♀ | R | G |
| | *Equus quagga* | Zebra | 290-340 kg ♂<br>290-325 kg ♀ | H | G |
| | *Hippotragus equinus* | Roan Antelope | 230-300 kg ♂<br>220-250 kg ♀ | R | B/G |
| **Large Bodied** | *Loxodonta africana* | Elephant | 5500-6000 kg ♂<br>3600-4000 kg ♀ | H | B/G |
| | *Syncerus caffer* | Buffalo | 750-820 kg ♂<br>680-750 kg ♀ | R | G |
| | *Giraffa camelopardalis* | Giraffe | 970-1395 kg ♂<br>700-950 kg ♀ | R | B |

# 4. Results

## 4.1 Tracks

The track ordination below shows the assemblages of animals and their similarities (Figure 4). These are identified by clusters of plots and related to three environmental variables, namely (soil type (WI and WF) and distance (DS). The impala is negatively related to distance, meaning that it is confined to the close vicinity of the water hole (200m). It is also positively related to white and fine soil and negatively related to white and intermediate soil. The giraffe, steenbok, warthog and grey duiker are also negatively related to distance and found at distances, 400m-1000m from the water hole. These animals are positively related to white and fine soil, but negatively related to white and intermediate soils. The zebra, tsetsebe and wildebeest are relatively negatively related to distance and to white and fine soil, but are positively related to white and intermediate soil. The elephant, roan antelope and kudu were all positively related to distance and white and intermediate soil, but negatively related to white and fine soil. The animals in this ordination are divided into three assemblages, the species in the first assemblage are negatively related to distance and negatively related to white and intermediate soils but positively related to white and fine soils. The species in the second assemblage are positively related to white and intermediate soil and slightly positively related to distance but negatively related to white and fine soils.

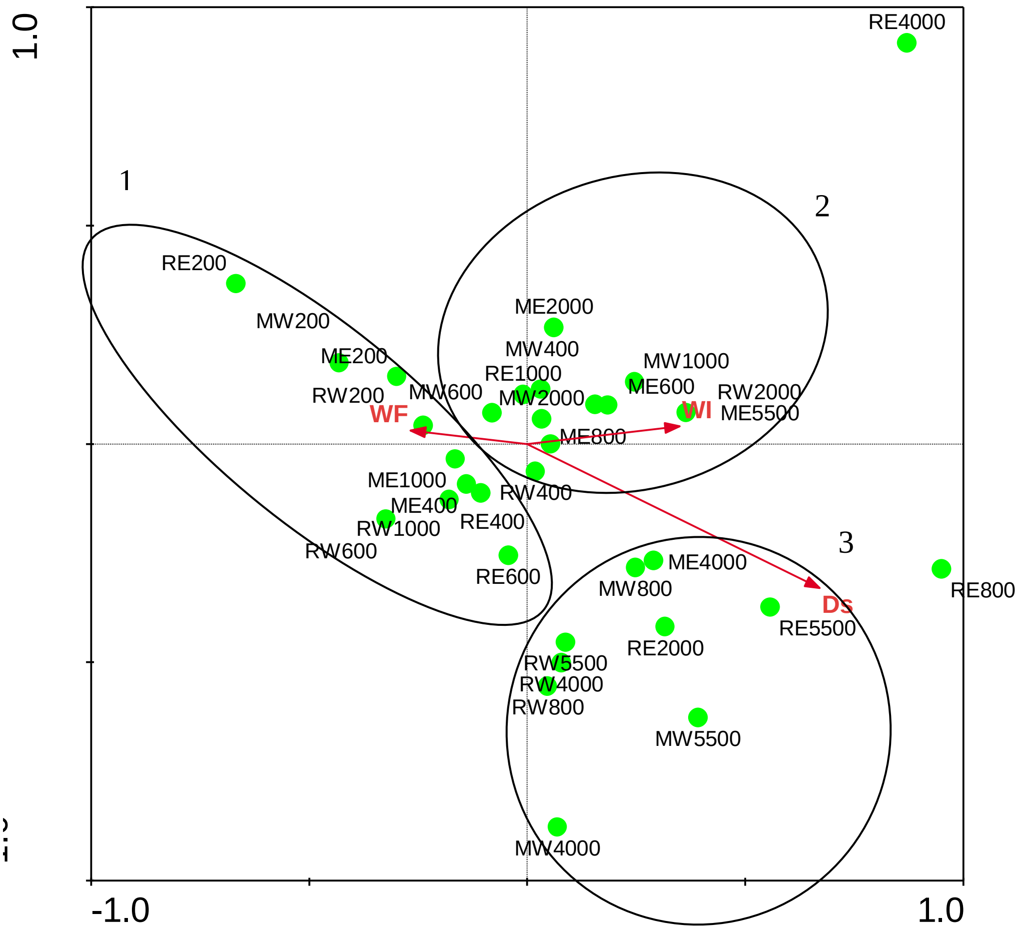


**Figure 4.** The CA ordination (tracks) above is showing the graphical assemblages of animals from the observed tracks and Environmental variables included in the graph which are significant: WI= white and intermediate soil (F =1.996; P = 0.048), WF = White and fine (F =1.825; P = 0.052) and DS = Distance (F =4.674; P = 0.002). The plot names represent the waterholes M=Marabou and R=Rhino and the transect directions by (E = east and W = west) and distance from waterhole in metres (m).

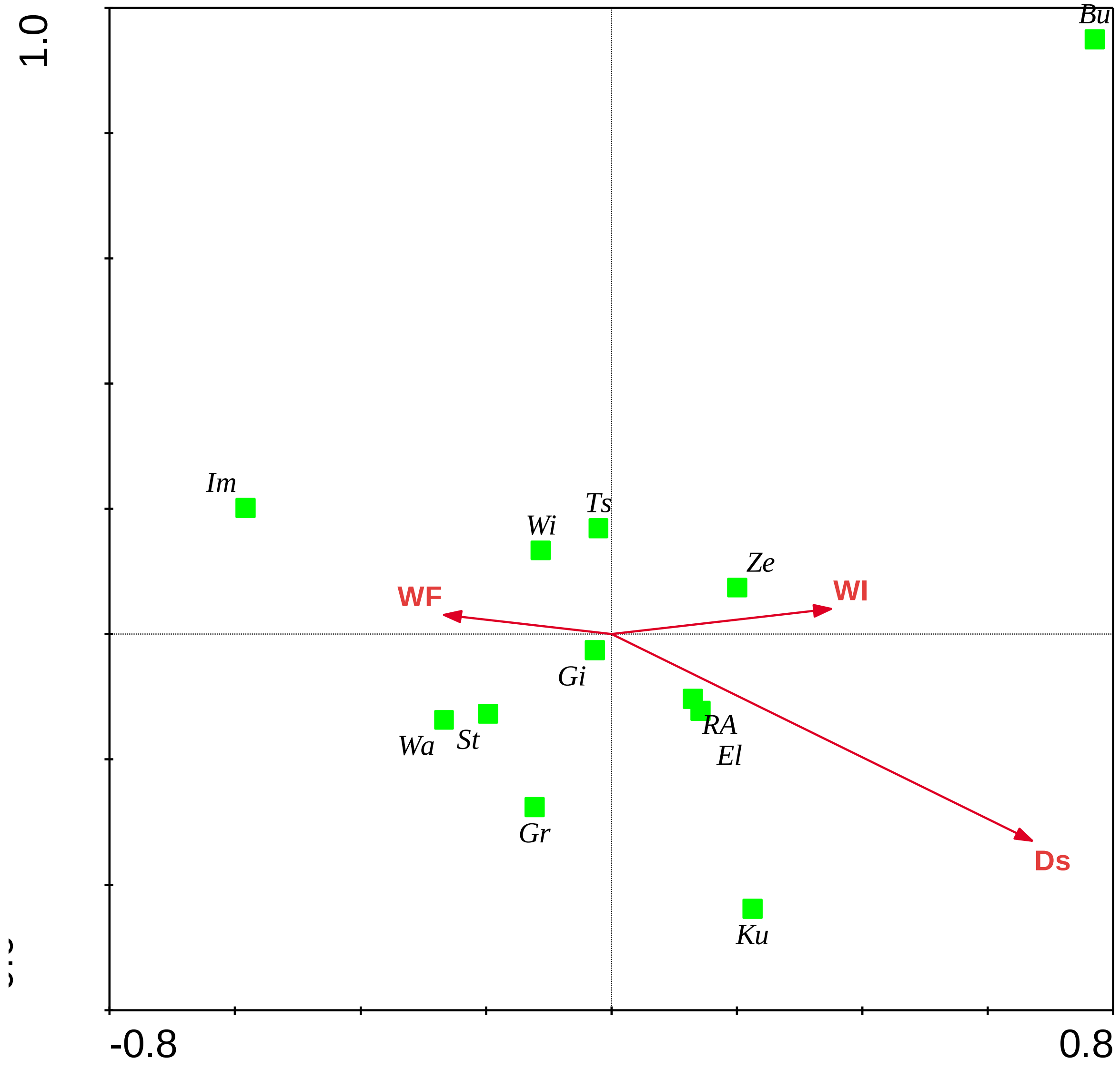


**Figure 5.** CA biplot is showing species ordination (track data) and environmental variables. The acronymes in the figure are: Impala = Im; Wilderbeest = Wi; Tsesebe = Ts; Zebra = Ze; Giraffes = Gi; Warthog = Wa; Steenbok = St; Grey Duiker = Gr; Roan Antelope = RA; Elephant = El; Kudu = Ku. Environmental variables included in the graph which are significant: WI= white and intermediate soil (F =1.996; P = 0.048), WF = White and fine (F =1.825; P = 0.052) and DS = Distance (F =4.674; P = 0.002).

The assemblages of mammals were separated along axes related to distances from the water holes. About 20% of the variation in the biplot is explained by the first axis in the (CA) figure 4 being the strongest, with an Eigenvalue of 0.199, and total inertia of 1.067.The canonical value = 0.230 (CCA), meaning that the graph explains about 23 % of the variation accounted for by the environmental variables. Forwards Selection with Monte Carlo Permutation test shows (CCA) that distance is significant with a p-value of 0.002, table 2, followed by white and intermediate soil with a p-value of 0.048**.** White and fine soil was slightly significant with a p-value of 0.052.

**Table 2**, f-values and p-values (Significance) of the different environmental variables. Distance = Ds, White and intermediate soil = WI, and White and fine = WF.

| | | |
|---|---|---|
| Ds | F-value = 4.674 | **P-value = 0.002** |
| WI | F-value = 1.996 | **P-value = 0.048** |
| WF | F-value = 1.825 | **P-value = 0.052** |

To examine the animal assemblages with similar characteristics, 3 clusters were put up to identify their relations in a CA ordination, Figures 4.

**4.1.1. Cluster 1**: The Impala's seem to be more common in abundance in this cluster, followed by both the elephant and wildebeest. The roan antelope was the least common in this cluster followed by the buffalo. Small species like the steenbok and the grey duiker also appeared in this cluster but in little numbers on average.

**4.1.2. Cluster 2**: The zebra appeared to be most common in this cluster followed by both the giraffe and wildebeest, whereas the least common species was the roan antelope and warthog. All other species appeared in little numbers on average e.g. the kudu, impala, buffalo and warthog in this cluster.

**4.1.3. Cluster 3**: This cluster was dominated in by the kudu's in abundance which was followed by the elephants. The least common species in this cluster was the buffalo and the roan antelope.

The proportion of tracks from the different species varied with distance from the water points (Figure 12). At 200m impala seem to be more common 30%, followed by wildebeest 14% and zebra 11%. The giraffe and elephant both follow just below 8% and the other species just below 5 %, e.g. the kudu and grey duiker. At 400m the wildebeest is more common just below 20%, followed by the elephant 17% and zebra 15%. The kudu and warthog are both just above 5% and the rest under 5%, e.g. impala and giraffe. At 600m the elephant is more common 25%, followed by the wildebeest 16%, zebra 13% and impala 12%. Both the giraffe and kudu are at 10% and the warthog below 5%. At 800m the elephants are more common 30%, followed by kudu 25% and giraffe 10%. The zebra is at 7% at 800m, followed by both wildebeest and grey duiker both at 5% and warthog which is appears the least 2%. At 1000m zebra are more common 24%, followed by elephants 15% and impala 12%. The wildebeest follows at 10% and the rest above 5 %, e.g. the warthog, grey duiker and the kudu. At 2000m the zebra is again more common 20%, followed the wildebeest 15%, elephant 13%, giraffe 12%, kudu 11% and the impala and grey duiker both below 5%. At 4000m kudu is most common 25%, followed by grey duiker 15%, elephant 4%, zebra 12%, wildebeest 10% and giraffe just below 5%. At 5500 the kudu is again more common 27%, followed by zebra 26%, elephant 25%, giraffe12%, warthog, impala, and wildebeest below 5%.

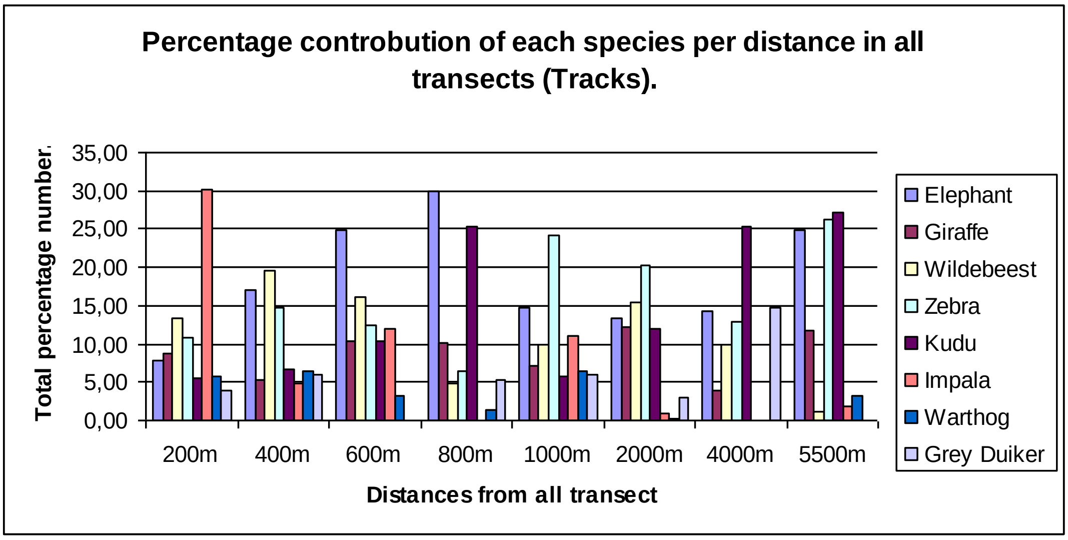


**Figure 6**, Percentage contribution of species per distance in all transects.

## 4.2 Faeces

The faeces ordination shows the assemblages of animals and their similarities (Figure 7). These are identified by clusters of plots and related to three environmental variables, namely (soil type (WI and WF) and distance (DS). The tsetsebe and wildebeest were negatively related to distance and to white and fine soil, but are positively related to white and intermediate soil. The impala is slightly negatively related to distance and positively related to white and fine soil, whereas the zebra is also slightly negatively related to distance, but positively related to white and intermediate soil. The giraffe is negatively related to distance and slightly positively related to white and intermediate soil. The kudu, elephant and buffalo are all positively related to distance and slightly positively related to white and fine soil, but negatively related to white and intermediate soil. The animals in this ordination where divided into three assemblages. The first assemblage of animals was negatively related to distance and slightly negatively related to white and fine soil but positively related to white and intermediate soil. In the second assemblage the animals were negatively related to white and fine soils and slightly negatively related to distance but positively related to white and intermediate soil. In the third assemblage the animals were positively related to distance and slightly positively related to white and fine soil but negatively related to white and intermediate soil.

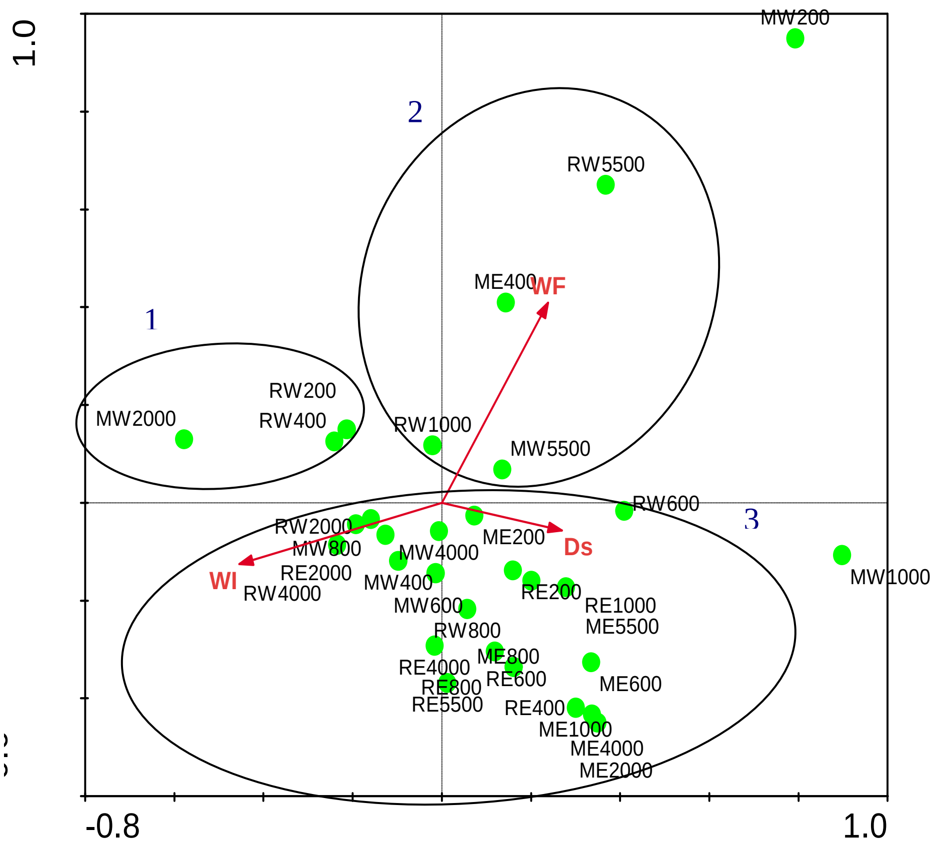


**Figure 7.** CA biplot is showing assemblages of animals from the observed faeces of different species and environmental variables. The acronymes in the figure are: Impala = Im; Wilderbeest = Wi; Tsesebe = Ts; Zebra = Ze; Giraffes = Gi; Warthog = Wa; Steenbok = St; Grey Duiker = Gr; Roan Antelope = RA; Elephant = El; Kudu = Ku. Environmental variables included in the graph which are significant: WI= white and intermediate soil (F =1.996; P = 0.048), WF = White and fine (F =1.825; P = 0.052) and DS = Distance (F =4.674; P = 0.002).

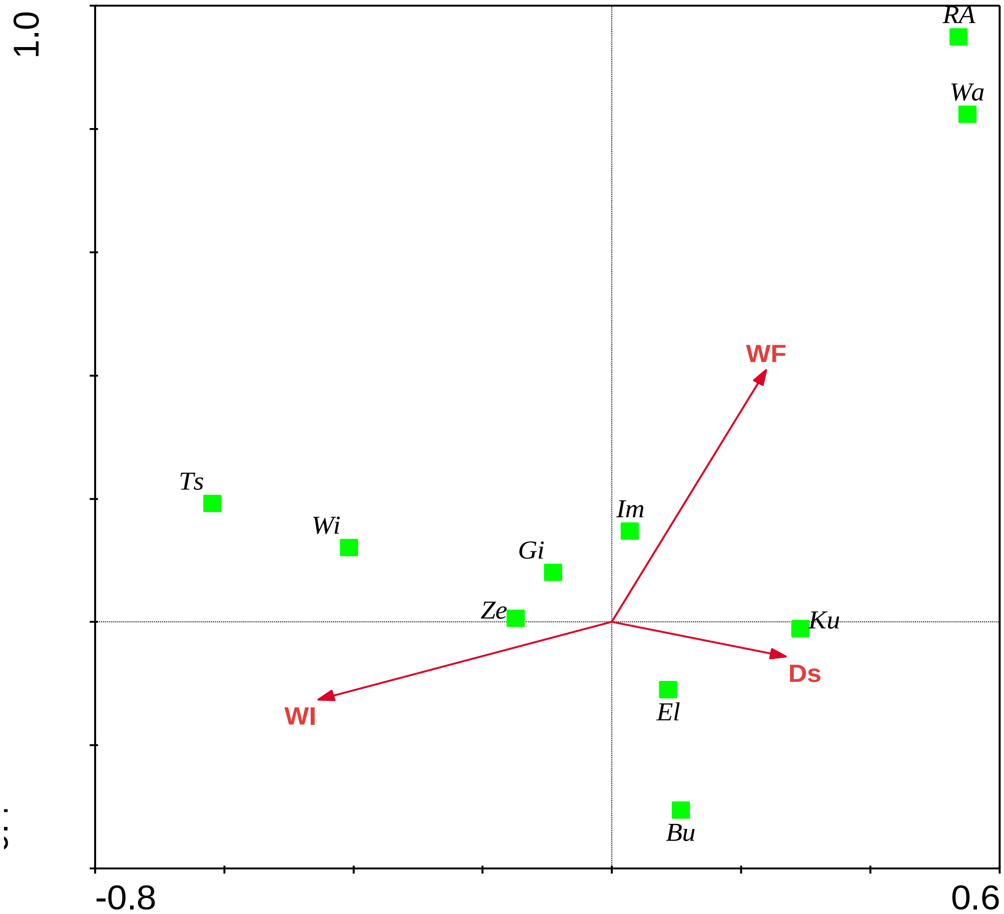


**Figure 8**. CA biplot shows an ordination of species and environmental variables. The acronymes in the figure are: Impala = Im; Wilderbeest = Wi; Tsesebe = Ts; Zebra = Ze; Giraffes = Gi; Warthog = Wa; Roan Antelope = RA; Elephant = El; Kudu = Ku; Buffalo = Bu. Environmental variables included in the graph which are significant: WI= white and intermediate soil (F =1.996; P = 0.048), WF = White and fine (F =1.825; P = 0.052) and DS = Distance (F =4.674; P = 0.002).

The assemblages of mammals were separated along axes related to distance from the water holes and to soil type. About 26% of the variation in the biplot is explained by the first axis in the figure 7, being the strongest, with an Eigenvalue of 0.255, and total inertia of 1.237. The canonical value = 0.228 (CCA), meaning that the graph explains about 23 % of the variation accounted for by the environmental variables.

Forwards Selection with Monte Carlo Permutation test (CCA) shows that distance significant with a p-value of 0.002, table 2, followed by white and intermediate soil with a p-value of 0.048**.** White and fine soil was slightly significant with a p-value of 0.052.

To examine animal assemblages by faeces count, 3 clusters were put up to identify their relation to each other in a CA ordination, (Figure 7).

**4.2.1. Cluster 1**: The elephant dominated this cluster in abundance followed by the wildebeest and the impala. The least common species in the cluster was the buffalo and the kudu.

**4.2.2. Cluster 2**: This cluster was dominated by the elephant which was followed by zebra and impala and the least common specie in this cluster was the buffalo.

**4.2.3. Cluster 3**: Elephant dominated this cluster in abundance followed by the zebra and wildebeest whilst the least common specie was again the roan antelope.

The proportion of faeces from the different species varied with distance from the water points (Figure 9). At 200m elephants are more common 45%, followed by impala 18%, warthog 11%, whereas the rest of the species seem to appear below 5%. At 400m the elephants are more common at 50%, followed by zebra 20%, wildebeest 10%, whereas the other species appear below 5 %. At 600m the elephants dominate again 59%, followed by zebra 18%, kudu 16% and impala at 5% appearance. At 800m elephants where more common 62%, followed by zebra 30%, giraffes 5% and kudu just below 5% appearance. At 1000m elephants are more common 42%, followed by kudu 28%, impala 18% and the ret below 5% appearance. At 2000m the elephants are more common 53%, followed by zebra 20%, giraffe 10% and the other species below 5%.

At 4000m the elephants are more common 48%, followed by zebra 30% whilst the rest of the species appeared just below 5%. At 5500m the elephants are more common 39%, followed by zebra 20%, kudu 10%, and giraffe 9% whilst the other species appeared at less than 5%.

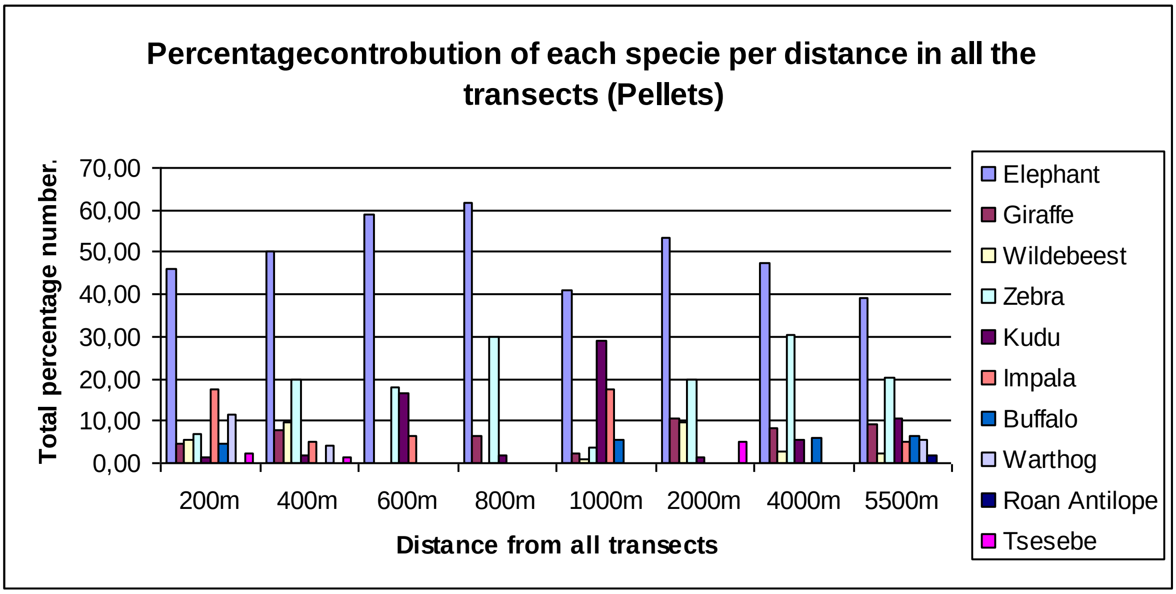


**Figure 9**, Percentage contribution of species per distance in all transects.

## 4.3 Visual Observation per plot

The groups of plots in the biplot are called clusters. This ordination shows the assemblages of animals and their similarities (Figure 10). These are identified by clusters of plots and related to three environmental variables, namely (soil type (WI and WF) and distance (DS).The giraffe, impala and zebra were negatively related to distance and to white and fine soil but slightly positively related to white and intermediate soil. A warthog and elephant were both negatively related to white and fine soil and positively related to both white and fine soil. The kudu was positively related to both distance and white and fine soil, but negatively related to white and intermediate soil. The species were divided in to three assemblages and in the first animal assemblage the animals were negatively related to distance and to white and fine soil, but positively related to white and intermediate soils. The animals in the second assemblage were negatively related to white and intermediate soils but positively related to distance and white and fine soil. In the third assemblage the animals were positively related to distance and white and fine soil, but negatively related to white and intermediate soil.

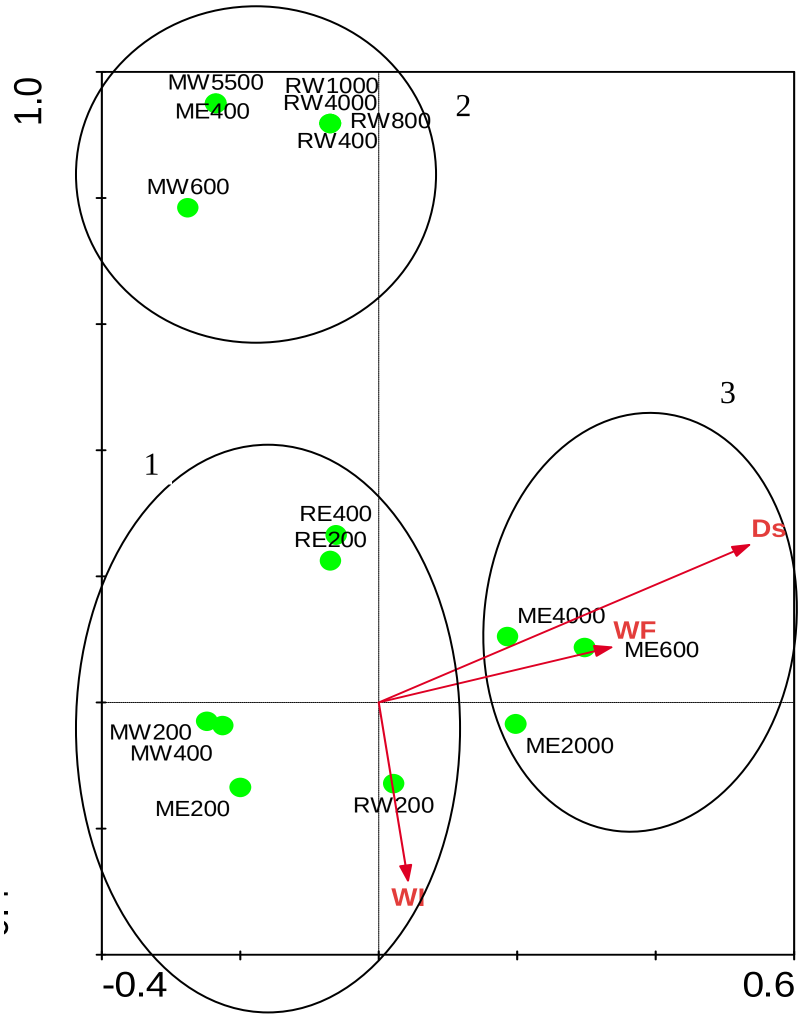


**Figure 10**. The CA ordination above is showing the graphical assemblages of animals from the observed species per plot. Environmental variables included in the graph which are significant: WI= white and intermediate soil (F =1.996; P = 0.048), WF = White and fine (F =1.825; P = 0.052) and DS = Distance (F =4.674; P = 0.002).. The plot names represent the waterholes M=Marabou and R=Rhino and the transect directions by (E = east and W = west) and distance from waterhole in metres (m).

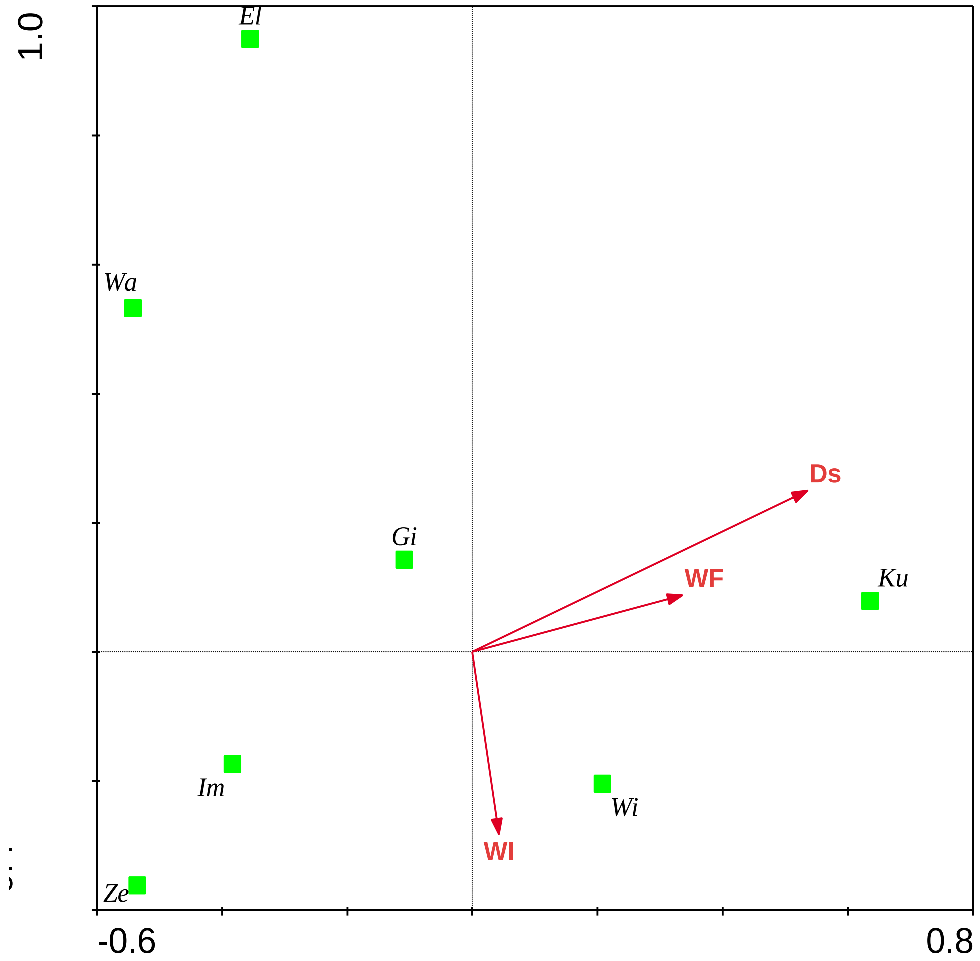


**Figure 11.** CA biplot is showing species distibution and three environmental variables. The figure also clearly shows the different species distribution. The acronymes in the figure are: Impala = Im; Wildebeest = Wi; Zebra = Ze; Giraffes = Gi; Warthog = Wa; Elephant = El; Kudu = Ku. Environmental variables included in the graph which are significant: WI= white and intermediate soil (F =1.996; P = 0.048), WF = White and fine (F =1.825; P = 0.052) and DS = Distance (F =4.674; P = 0.002).

The assemblages of mammals were separated along axes related to distances from the water holes. About 69% of the variation is explained by the first axis in the figure 7 being the strongest, with an Eigenvalue of 0.694, and total inertia of 1.786. The canonical value = 0.581 (CCA), meaning that the graph explains about 58 % of the variation accounted for by the environmental variables. Forwards Selection with Monte Carlo Permutation test (CCA) shows that distance significant with a p-value of 0.002, table 2, followed by white and intermediate soil with a p-value of 0.048**.** White and fine soil was slightly significant with a p-value of 0.052.

To examine the animal assemblages, 3 clusters were put up to identify their similarities in a CA ordination, (Figure 10).

**4.3.1. Cluster 1**: Impala was more common in this cluster in abundance whilst the least common species was the warthog and zebra.

**4.3.2. Cluster 2**: The cluster had only two species, elephant and warthog. The elephant was more common in abundance in this cluster.

**4.3.3. Cluster 3**: This cluster contained only three species and the kudu was more common followed by the wildebeest and giraffe. The least common of these species was the giraffe.

The figure 12, below represents the % contribution of each species at each distance. At 200m impala was more common 65%, followed by both elephants and wildebeest at 12% appearance, whilst the other species appeared below 5%. At 400m the elephant are more common 57%, whilst the other specie appeared below 5%. At 600m zebra are most common 25%, followed by elephants 15% and warthogs 10%. At both 800m and 1000m elephant are most common both 25%. At 2000m zebra are more common 13%, followed by wildebeest 10%. At 4000m elephant are more common 25%, followed by 18% and giraffe 8%. At 5500m elephants are more common 25%.

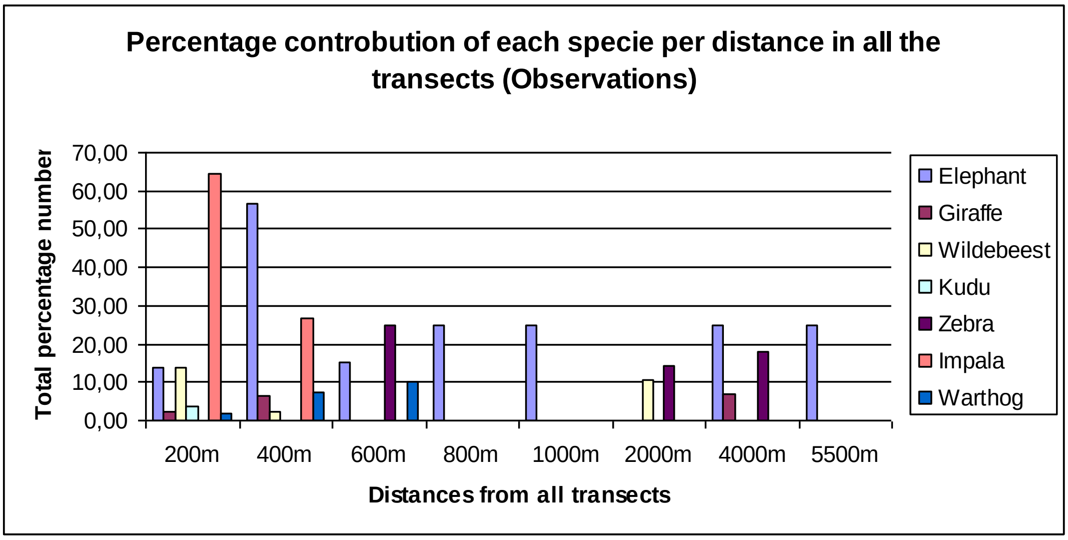


**Figure 12**, Percentage contribution of species per distance in all transects.

**Table 2**, below shows the total numbers of tracks, faeces and observations observed during data collection. It also shows the total numbers of observed tracks, faeces and visual observations per transect. Abbreviations are as follows, Rhino east transect = RE, Rhino west transect = RW, Marabou east transect = ME and Marabou west transect = MW.

| | **Totals:** | **RE** | **RW** | **ME** | **MW** |
|---|---|---|---|---|---|
| **Tracks** | 2331 | 625 | 735 | 669 | 302 |
| **Faeces** | 1505 | 452 | 467 | 292 | 293 |
| **Observations** | 495 | 24 | 110 | 243 | 118 |

## 4.4 Proportion of species in relation to soil type

Assemblages differed in composition (% contribution of each species) between soil types counted as tracks, pellets and visual observations, (Figure 13, 14 and 15).

The animal preference of the soil type differed as the amount of tracks shows, with elephants showing the most tracks in the two last soil types (GF and GI), while zebras and kudus tracks were the most at WF and WI respectively, whereas fewer tracks were shown by buffalo, warthog at WF and WI in that order. At GF soil type buffalo tracks were seen and at GI soil type roan antelope tracks were not seen.

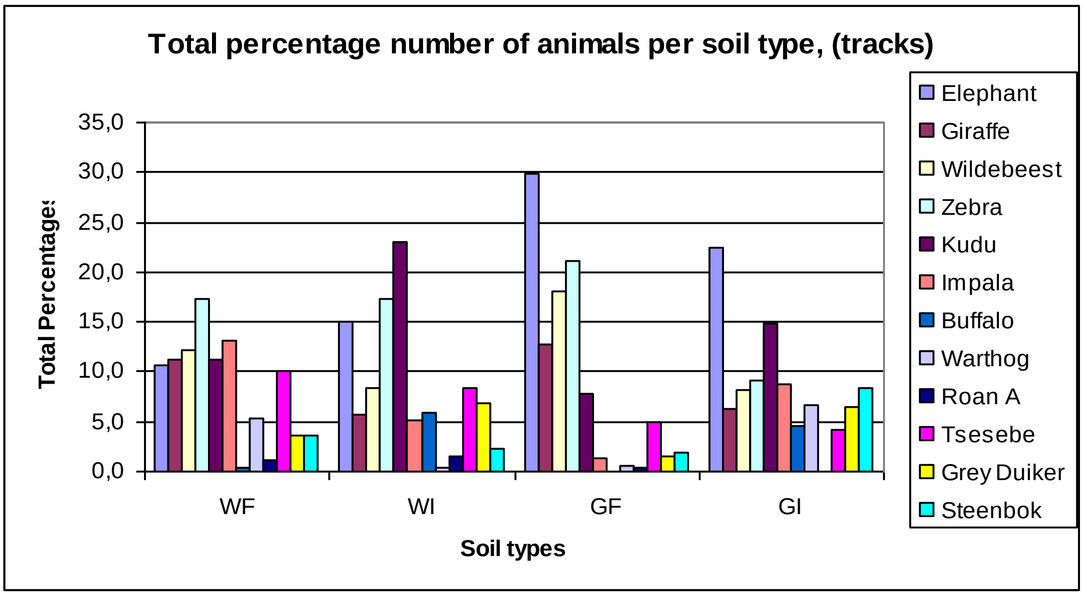


**Figure 13,** shows the total percentage number of animals per Soil type (Tracks). The acronyms in the figure are: white and intermediate soil = WI, White and fine soils = WF, Grey and fine = GF and Grey and intermediate = GI.

The elephants showed the highest percentage contribution of pellets at all soil types (WF, WI, GF and GI) followed by zebras. On soil type WF roan antelope pellets percentage was the lowest, whereas on WI and GI warthog pellets percentages were the lowest and on GF it was the tsetsebe. The first two soil type (WF and WI) showed most types of animals faeces followed by the other two soil types.

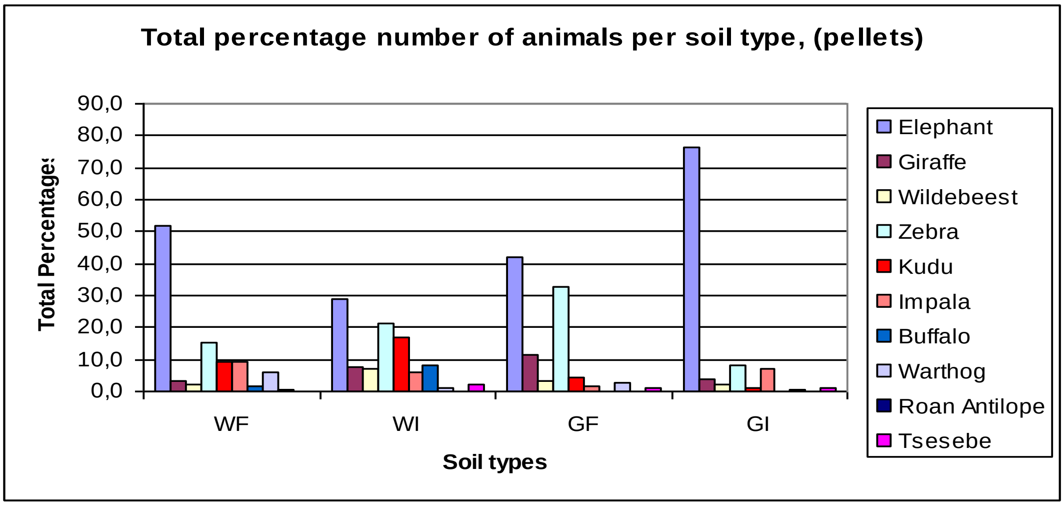


**Figure 14,** shows the total percentage number of animals per Soil type (Faeces). The acronyms in the figure are: white and intermediate soil = WI, White and fine soils = WF, Grey and fine = GF and Grey and intermediate = GI.

The percentage contribution of elephant observed were the highest at all soil types followed by zebras at WF soil type and impala at the rest of the soil types (WI, GF and GI). Whereas the giraffe and warthog were observed the lowest on WF and GF soil types, wildebeest on WI soil and giraffe on GI soil type. Soil type WF and GI had the most different types of animals observed.

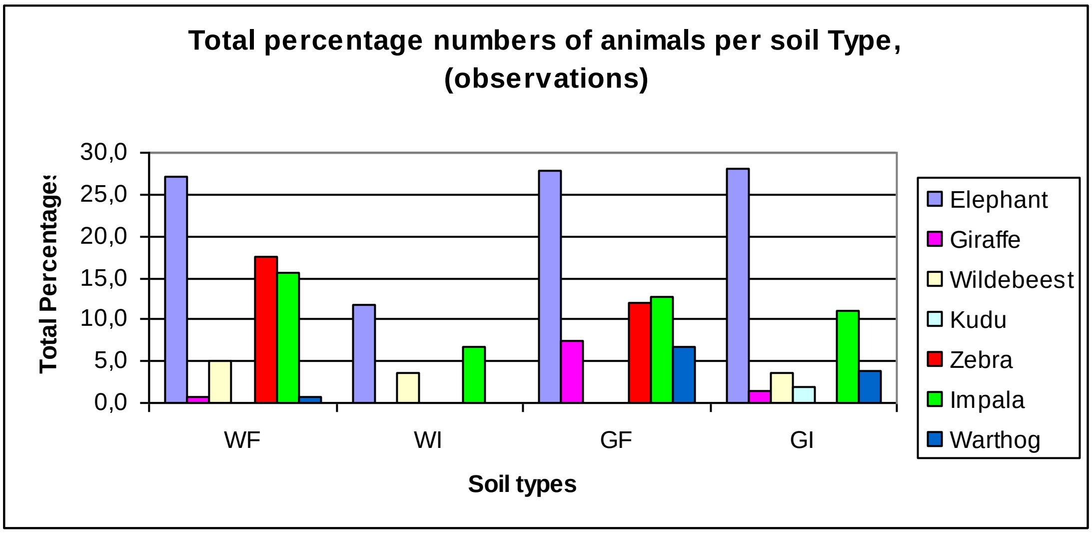


**Figure 15,** shows the total percentage number of animals per Soil type (Visual observations). The acronyms in the figure are: white and intermediate soil = WI, White and fine soils = WF, Grey and fine = GF and Grey and intermediate = GI.

The results from the three methods used above (track, faeces and observation ordinations) presented differences in assemblages of animals and their relation to soil types (Figures 4, 5, 7, 8, 10 and 11). The impala seemed consistently confined to the close vicinity of the water holes and is consistently negatively related to white and intermediate soil in all ordinations Figures 4, 5, 7, 8, 10 and 11. The wildebeest, tsetsebe and zebra seem to also be negatively related to distance and slightly negatively related to white and intermediate soil. The roan antelope, kudu, elephant and buffalo appeared to be constantly positively related to distance but negatively related to white and fine soil. This shows that body size and mobility ability does play a role in the patterns of animal distribution around artificial water holes, even though in some cases animals of intermediate body sizes that were expected to be more intermediate in their dispersals were found at distances either too close to the water hole or further away from water hole than expected. The giraffe which is considered as a large bodied animal seem to be more intermediate in dispersal, meaning that it was neither found to far nor to close to the water hole.

# 5. Discussion

I tested the hypothesis that animal presence would decrease with increasing distance from the water holes and that all small bodied water depending species would be most confined to the immediate vicinity of water, whereas larger bodied species, particular hind gut fermenting animals like elephants would respond least to the distance. The results agree with the hypothesis that in general all animal densities did decrease with increasing distance from the water holes except for the elephant that reacted least to distance (Figures 5, 8 and 11). The elephant (hind-gut fermenter) as expected seem to have been evenly distributed along the landscape, meaning that they were not affected by distance at all (Figures 6, 9 and 12), (Jammes et al. 2007 and Loarie et al. 2009). The animals were not distributed according to their digestive systems, but rather by body size, meaning animals of different digestive systems in some case were found in the same areas. Small bodied animals like the impala (mix feeder) and steenbok (browser) were mostly confined to the immediate vicinity of the water, whereas the intermediate bodied sized animals like the tsetsebe (grazer), wildebeest (grazer), zebra (hind-gut fermenter) and roan antelope (mix feeder) were distributed further away from the waterholes when compared to the impala. This could be because water necessities are said to generally scale with body size as shown by (du Toit 2002, Brown 2006). Impala's and warthogs are well known for being seen close to the vicinity of water whereas steenbok and grey duiker even though small bodied and also water dependent can venture at far off from the closest water point. The roan antelope is one that known to be further away from the water points as shown in Smit et al. (2006) even if it said to be very water dependent, it is also known to be very shy and avoids open areas making them rare to see around water holes and this is maybe why the roan antelope was found far away from the water points (Figures 5 and 8). Wildebeest, tsetsebe and zebra are all said to be very water dependent but move reasonable distance from the water hole to forage (Smit et al. 2009). Mobility is another factor that could have influenced the distributions of species around water points, some species like elephant, kudu, buffalo and roan antelope are known to walk long distances from the water points (Smit et al. 2006) to feed whereas smaller species like the impala preferably feed closer to the water. This could be explained by the wider food quality tolerance which allows large bodied species to use a higher diversity of habitat types, thus why species of different bodied sizes showed differences in dispersal from the water holes, especially the buffalo, and particularly the elephant which is a hind-gut fermenter (Bell, 1971). This allows the large bodied species to use larger proportion of the landscape by using a higher diversity of habitats, including those of low resource quality for the smaller species.

Redfern, (1995) suggested that water availability constraints imposed on herbivore distributions have shown to vary between feeding guilds and Western, (1975) found that browsers tend to occur further from water than grazers, this doesn't seem to agree fully with our result because the buffalo (grazer) in this paper was mostly found furthest away from the water holes and other grazers like the zebra were rather intermediate with distance. Smit et al. (2007) suggested that herbivores do infact exhibit different distribution patterns around water holes. They found out that the grazer's species associated more with artificial waterholes, whereas the browsers and mixed feeders were indifferent to the water holes suggesting that they were not confined to the water holes. Owen-Smith, 1996 suggested that species most impacted by water availability are to have the highest biomass density within the grazer community, for e.g. the buffalo, zebra, and wildebeest. Redfern, 1995 found that impala herd densities decreased with increasing distance to the water hole, while the distributions for wildebeest, giraffe, kudu, and zebra were characterized by a weaker relationship between assemblages and distance-to-water. In addition the results suggest that herbivore distance to water distributions differ in the soil substrate-defined in figure 13, 14 and 15. Some species like the impala, warthog, steenbok, grey duiker, giraffe, wildebeest and tsetsebe seems to be more confined to white and intermediate particle soils, whereas the zebra, roan antelope and elephant, kudu and the buffalo seem to be more common on white and fine particle soils.

# 6. Conclusion

In this paper I looked at the wet season distribution of herbivore species in relation to artificial waterholes respectively. The results provide the empirical proof as to which species associate with artificial waterholes on a spatial and temporal scale in Savuti. Furthermore, the results indicate that ecological processes or habitat characteristics associated with the distribution of waterholes act as strong drivers of herbivore distributions in semi-arid African savannas. This is evident as consistencies within and differences between distribution patterns of herbivore feeding groups (grazers, browsers and mixed feeders) on different geological soils types. Artificial waterholes are therefore just artificial features in the landscape that can change the distribution of large African herbivores, even in a landscape where natural water is accessible. In the future it would be of importance to do a dry season study of the same study in order to compare the results. Even though I was able to see distribution patterns of different body sizes species around the artificial water holes, I suggest a dry season study be done since this would clarify better the animal assemblages in the ordinations of the present thesis because there would be a limitation to only artificial waterholes , meaning that it would be easier to identify species assemblage patterns and their ability to distribute.

# 7. References


1. Aava, B. 2001. Primary productivity can effect mammalian body size frequency distribution. *Oikos* 93 : 205-212

2. Andrew,M. H., 1988. Grazing impact in relation to livestock watering point. *Trends in Ecology and Evolution*, 3: 336-339

3. Barnes, C. 1991. *Savuti: the Vanishing River*. Southern Book Publishers. Halway House, South Africa

4. Baxter, P. W. J. and Getz W. M. 2005. A model-framed evaluation of elephant effects on tree and fire dynamics in African savannas. *Ecological application* 15 (4): 1331-1341

5. Bell, R. H. V.1971. A grazing ecosystem in the Serengeti. *Scientific American* 225: 86-94

6. Ben-Shahar, R. 1995. Woodland dynamics under the influence of elephants and fire in northern Botswana. *Vegetatio* 123 (2): 153-163

7. Chamaille´-Jammes, S., Valeix, M and Fritz, H. 2007. Managing heterogeneity in elephant distribution: interactions between elephant population density and surface-water availability. *Journal of Applied Ecology* 44 (3): 625–633

8. Cillie, B. 2007. *The mammal guide of Southern Africa*. Briza publication, South Africa, Pretoria, Page 16- 100

9. Coughenour, M.B. 2008. *Causes and consequences of herbivore movement in landscape ecosystem. Natural Resource Ecology Laboratory*. Colorado State University. Fort Collins, USA

10. Cromsigt, J. P. G. M., Prins, H. H. T and Olff, Han. 2009. Habitat heterogeneity as a driver of ungulate diversity and distribution patterns: interaction of body mass and digestive strategy. *Diversity and Distributions* 15:513-522

11. Dublin, H. T., Sinclair, A. R. E., McGlade, J., 1990. Elephants and fire as causes of multiple stable states in the Serengeti- Mara woodland. *Journal of Animal. Ecol.* 59, 1147-64

12. du Toit, J. T. 1995. Determinants of the composition and distribution of wildlife communities in Southern Africa. *Ambio* 24(1): 2-6

13. du Toit, J. T and Cumming, D. H. M. 1999. Functional significance of ungulate diversity in African savannas and the ecological implications of the spread of pastoralism. *Biodiversity and Conservation* 8: 1643-1661

14. du Toit, J. T. 2002. Wildlife harvesting guidelines for community-based wildlife management: A southern African perspective. *Biodiversity and Conservation* 11: 1403-1416

15. Epaphras, M. A., Gereta, E., Lejora, A. I., Ole Meing'ataki, G. E., Ng'umbi, G., Kiwango, Y., Mwangomo, E., Semanini, F., Vitalis, L., Balozi, J., Mtahiko, M. G. G. 2007. Wildlife water utilization and importance of artificial waterholes during dry season at Ruaha National Park, Tanzania. *Wetlands ecology and management* 16:183-188

16. Fernandez, H. M and Vrba, E. S. 2005. Body size, biomic specialisation and range size of African large mammals. *Journal of Biogeography* 32: 1243 – 1256

17. Forman, T. T. And M. Godron, 1981. Patches and structural components for land scape. *Ecology, Bioscience*, 31: 733-740

18. Gauch, H. G. 1982. *Multivariate analysis in community ecology*. University of Cambridge. New York, USA. Page 1-3

19. Hair, J., Black, W., Babin, B., Anderson, R. 2009. Multivariate data analysis. Prentice Hall.

20. Jammes, S. C., Valeix, M., and Fritz, H. 2007. *Managing heterogeneity in elephant distributions: interactions between elephant population density and surface-water availability.* Campus International de Baillarguet, France

21. Kalwi, J.M., De Boer, W. F., Mucina, L., Prins, H. H. T., Skarpe, C and Winterbach. 2009. Tree cover and biomass increase in a southern African savannah despite growing elephant population. *Ecological Applications*. 20 (1): 222-233

22. Knight, M. H., 1995. Drought related mortality of wildlife in the southern Kalahari and the role of man. African Journal of ecology. 33, 377-394

23. Lange, R. T. I. 1969. The piosphere: Sheep track and dung patens. *Range Management* 22: 396-400

24. Leps, J and Smilauer, P. 2003. *Multivariate analysis of ecological data using CANOCO.* Cambridge University Press

25. Leuthold, W., Leuthold, B. M.1973. *Ecological studies of ungulates in Tsavo (East) National Park, Kenya.* Tsavo Research Project, Kenya National Parks. Page 67

26. Loarie, S. R., Vann Aarde, R. J., and Pimm, S. L. 2009. Fences and artificial water affect African savannah elephant movement patterns. *Biological conservation* 142 (12): 3086-3098

27. Makhabu, S. W. 2005. Resource partitioning within a browsing guild in a key habitat, the Chobe Riverfront, Botswana. *Journal of Tropical Ecology* 21 (6): 641-649

28. Moe, S.R., Rutina, L.P., duToit, J.T and Hytteborn, H. 2008. What controls woodland regeneration after elephants have killed the big trees? *Journal of Applied Ecology* 46 (1): 223-230

29. Mordi, A. R. 1989. The Future of Animal Wildlife and its habitat in Botswana. *Environmental Conservation* 16 (2): 147-156

30. Mosugelo, D. K., Moe, S. R., Ringrose, S and Nelleman, C. 2002. Vegetation changes during a 36-year period in northern Chobe National Park, Botswana. *African Journal of Ecology* 40 : 232–240

31. Olff, H., Ritchie, M.E and Prins, H.H.T. 2002. Global environmental controls of diversity in large herbivores. *Nature* 415: 901-904

32. Owen-Smith. 1996. Ecological guidelines for water points in extensive protected areas. South African *Journal Wildlife Research* 26 (4): 107-112

33. Phillipson, J. 1975. Rainfall, primary production and "carrying capacity" of Tsars National Park, Kenya. *East African Wildlife Journal* 18 (4): 171-201

34. Power, R. J and Compion, R. X. S. 2009. Lion predation on elephants in Savuti, Chobe National Park, Botswana. *African Zoology* 44(1):36-44

35. Redfern, J. V. 2002. *Manipulating surface water availability to manage herbivore distribution in the Kruger National Park, South Africa.* PhD thesis. University of California. Berkeley

36. Sinclair, A. R. E. 1974. Natural regulation of a buffalo population in East Africa. *East African Wildlife Journal* 12: 135-154

37. Stokke, S. & du Toit, J. T. 2000. Sex and size related differences in the dry season feeding patterns of elephants in Chobe National Park, Botswana. *Ecography* 23 (1): 70-80

38. Smit, I. P. J., Grant, C. C., Devereux, B. J. 2006. Do artificial waterholes influence the way herbivores use the landscape? Herbivore distribution patterns around rivers and artificial surface water source in a larger African savanna park. *Biological Conservation* 136:85-99

39. Smit, I. P. J., Grant, C. C. 2009. Management surface-water in a large semi-arid savanna park: Effects on grazer distribution patterns. *Journal of nature conservation* 17 (2): 61-71

40. ter Baak, C. J. F. 1989. CANOCO- an extension of DECORANA to analyse species-environment relationships. *Hydrobiologia* 184: 169-170

41. Valeix, M. H., Fritz, S. Dubois, K. Kanengoni, S., Alleoume, S., Said 2007. Vegetation structure and ungulate abundance over a period of increasing elephant abundance in Hwange National Park, Zimbabwe. *Jounals of Tropical Ecology* 23, 87-93

42. Walker, C. 1991. *Acacia woodland ecology and elephant in northern Botswana*. PhD thesis. University of Nevada. Reno, U.S.A

43. Walker, C. 2007. *Signs of the wild. A field guide to the spoor & signs of the mammals of Southern Africa.* Struik Publishers, Cape Town. Page 158- 210

44. Watson, R. M. 1972. *Results of aerial livestock sm'veys of Kaputei division, Samburu district and North-eastern Province. Statistics division, Min. of Finance and Planning*. Republic of Kenya. Page 111

45. Western, D. 1975. Water availability and its influence on the structure and dynamics of large mammal community. *East African Wildlife Journal* 13:265–286

## Internet sites

The map in this paper was found in (Kalwij *et al.* 2009). The lower right map just below the first one was found in (http://www.dktours.co.zw/images/CHOBE.gif) 17.01.2010. Small changes were made in the map (red dot) by Martin Skram Vatne in his masters' thesis (2009)